

**Abstract.** Australia Telescope Compact Array H I observations reveal the existence of  $5.8 \cdot 10^8 M_{\odot}$  of H I gas in the central 7 kpc of the edge-on spiral galaxy NGC 3175. The detected H I and CO gas can explain why star formation, as traced by other emission processes, is going on in the inner part of its disk. On the other hand, the entire outer disk, beyond 3.5 kpc radius, shows no H I emission, has a very red colour and exhibits neither radio continuum nor H $\alpha$  emission. This indicates that the outer part of NGC 3175 is quiescent, i.e. not forming stars at a measurable rate. Its H I deficiency and the small extent of the H I layer, which is confined to the boundaries of the optically visible disk, make NGC 3175 a peculiar spiral galaxy. No intergalactic H I gas in the NGC 3175 group was detected in our interferometric observations. Earlier Parkes telescope single dish H I observations put an upper limit on the amount of diffuse gas that might have been missed by the interferometer at  $2 \cdot 10^8 M_{\odot}$ . On DSS plates no galaxy in the NGC 3175 group of galaxies (García 1993) is close enough to it and none exhibits disturbances that could indicate a close interaction which might have led to the stripping of large parts of its H I gas. Thus, despite an extensive multi-wavelength investigation, the reason for the unusual absence of H I and star formation activity in the outer disk of NGC 3175 remains an intriguing mystery.

**Key words:** Galaxies: evolution – Galaxies: general – Galaxies: individual: NGC 3175 – Galaxies: interactions – Galaxies: ISM – Galaxies: spiral

# The mysterious HI deficiency of NGC 3175

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## 1. Introduction

A large number of “typical” global properties of galaxies of various Hubble types are presented and discussed by Roberts & Haynes (1994; in the following RH94). We will use these as standard reference values, with respect to which we will discuss our results from HI observations of the southern edge-on spiral galaxy NGC 3175. RH94, as well as e.g. Rhee & van Albada (1996), determined that typical  $L_*$  spiral galaxies, i.e. galaxies near the “knee” of the galaxy luminosity function, with an absolute  $B$  magnitude of  $M_B \simeq -20$ , normally have HI gas masses on the order of  $10^9 - 10^{10} M_\odot$ . This usually represents a few percent of their total mass (RH94). The spatial distribution of HI gas is usually more extended than that of the stellar disk (Bosma 1981).

With respect to its global properties the edge-on spiral galaxy NGC 3175 is quite peculiar. Its Hubble type is uncertain; the Third Reference Catalogue of Bright Galaxies (RC3; de Vaucouleurs et al. 1991) classifies it as SAB(s)a?, while it is listed as Sc in the Revised Shapley-Ames Catalog (RSA; Sandage & Tammann 1981). In the Uppsala General Catalog of Galaxies (UGC), Nilson (1973) claims that de Vaucouleurs’ classification (which had been taken over from the RC2) is incorrect and that NGC 3175 is “probably a late-type galaxy”. Because of this confusion, we will compare its global properties with those of galaxies ranging from type Sa to Sc.

Although at a redshift of only 1098 km s<sup>-1</sup> (and thus at a distance of only 15.9 Mpc)<sup>1</sup>, this galaxy was, until a few years ago, not detected in HI emission (Mathewson et al. 1992). Recently, Mathewson & Ford (1996) and Theureau et al. (1998) found weak HI emission from NGC 3175. Despite this difficulty in tracing its HI gas, it has been readily detected in H $\alpha$  (Ryder & Dopita 1993, 1994), radio continuum (Condon et al. 1996) and CO emission (Elfhag et al. 1996), which are tracers of star forming regions. The Infra-Red Astronomical Satellite (IRAS)

measured 60  $\mu$ m and 100  $\mu$ m fluxes of 13.1 and 28.2 Jy, respectively. With an  $f_{60}/f_{100}$  flux ratio of 0.46, tracing warm dust, and in the absence of a luminous AGN, this galaxy is obviously forming stars that heat the interstellar medium (ISM) and dust in its disk. The detection of CO emission in the central part of NGC 3175 proves that there is molecular gas from which stars can form. On the other hand, with only barely detectable HI emission, it is not clear where NGC 3175 has its gas reservoir from which to form stars in the future. We investigate this riddle here based on new HI observations conducted with the Australia Telescope Compact Array (ATCA)<sup>2</sup>.

## 2. Observations and data reduction

Our ATCA observations were obtained on 1997, Jan. 27–28, with the 750D configuration over a timerange of 13 hours. The total on-source integration time is 10 h. The ATCA correlator setup used by us provides a velocity resolution of 3.3 km s<sup>-1</sup>.

1934-638 was used as the primary flux calibrator and 1012-44 as phase calibrator. The measured flux of 1934-638 was 14.94 Jy at 1.42 GHz. The data reduction was performed in the standard fashion, using the software package MIRIAD. In order to achieve maximum sensitivity for extended emission, natural weighting of the visibilities was used. The disadvantage of this procedure, namely the low angular resolution of the images, is secondary for the current study.

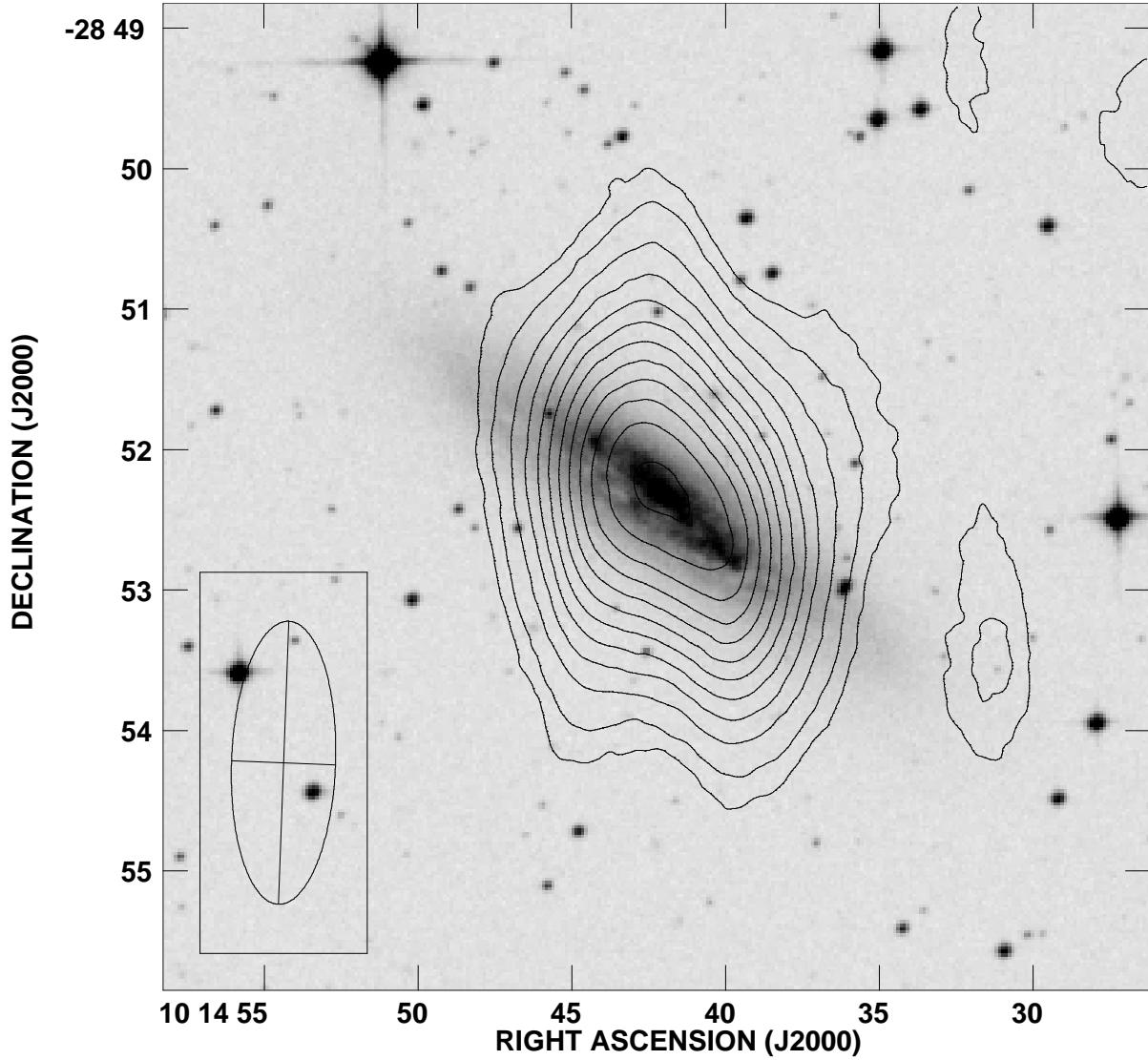
With an angular extent of its radio emission of only a few arcmin (see below), NGC 3175 fits easily into the primary beam of the ATCA’s 22 m antennae of 34'. Therefore, no primary beam correction is necessary. With a shortest spacing of 31 m, flux losses due to missing short spacings are negligible.

## 3. Results

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<sup>1</sup> We adopt here  $H_0 = 75$  km s<sup>-1</sup> Mpc<sup>-1</sup> and a virgocentric infall velocity of 300 km s<sup>-1</sup>.

<sup>2</sup> The Australia Telescope is funded by the Commonwealth of Australia for operation as a National Facility managed by CSIRO.



**Fig. 1.** HI total intensity map of NGC 3175, with a resolution ( $FWHM$ ) of  $121'' \times 44''.5$  (see beam profile in the lower left), overlaid on a Digital Sky Survey image. The contour levels are  $0.42, 0.6, 0.9, 1.2, 1.5, \dots 3.6 \text{ Jy beam}^{-1} \text{ km s}^{-1}$ .

### 3.1. HI distribution

Figure 1 displays our ATCA image of the total HI emission from NGC 3175, superposed as contours on a Digital Sky Survey (DSS) image. The angular resolution ( $FWHM$ ) of the HI image is  $121'' \times 44''.5$ , as indicated in the lower left. The emission is marginally resolved along the disk plane of the galaxy in what appears to be a double-peaked distribution.

A cut through the HI emission distribution along the galaxy's major axis, for which we adopt a position angle of  $PA = 51^\circ$  (Dahlem et al. 2001), is displayed in Fig. 2. In this figure the data are represented by a solid line.

It became clear very soon during our spatial analysis of the emission distribution that a two-component approximation is not adequate. Thus, a three-gaussian model was computed and graphically displayed. The individual gaussians and the sum of the three are represented by dotted lines. The remaining residual is shown as a bold dashed line. The width of  $67''.7$  of all three gaussians is identical; it represents the resolution of our data in the direction of the major axis over the width of the cut of  $35''$ . The fact that the three gaussians leave virtually no residuals indicates that most of the HI line emission arises from three maxima, with almost no emission from further out in the disk. The positions of the three gaussian components along the

**Table 1.** Positions and intensities of emission components along the major axis of NGC 3175

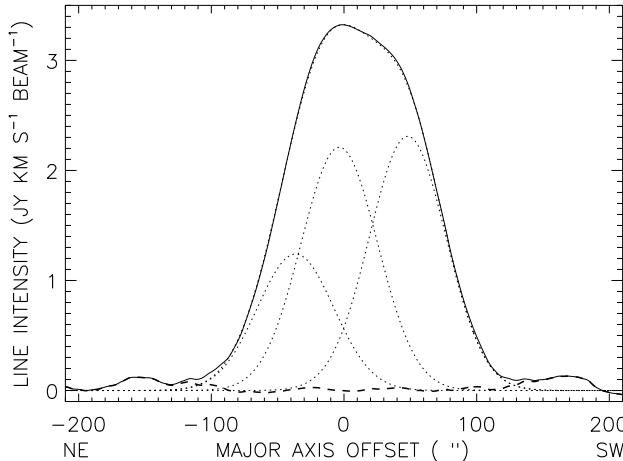
Component	HI Emission Line <sup>a</sup>			1.49 GHz Continuum <sup>b</sup>		
	Radial Offset ( $''$ )	(kpc)	Relative <sup>c</sup> Intensity	Radial Offset ( $''$ )	(kpc)	Relative <sup>c</sup> Intensity
NE	$-37.0 \pm 3.0$	$-2.86 \pm 0.23$	$0.56 \pm 0.03$	$-16.7 \pm 0.5$	$-1.29 \pm 0.04$	$0.49 \pm 0.02$
Centre	$-4.0 \pm 3.0$	$-0.32 \pm 0.23$	$1.00 \pm 0.02$	$0.0 \pm 0.5$	$0.00 \pm 0.04$	$1.00 \pm 0.01$
SW	$+47.5 \pm 3.0$	$+3.66 \pm 0.23$	$1.05 \pm 0.02$	$+14.5 \pm 0.5$	$+1.12 \pm 0.04$	$0.34 \pm 0.03$

Notes to Table 1:

a) Our data.

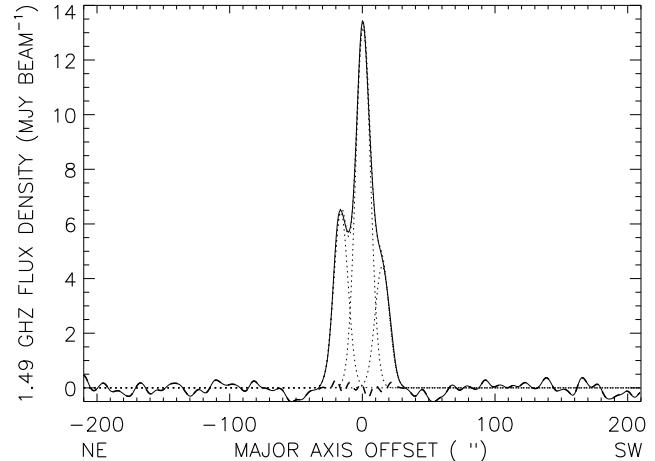
b) Condon et al. (1996).

c) The intensity of the central peak was normalised to unity.



**Fig. 2.** Cut through the HI line emission distribution of NGC 3175 along its major axis. The width of each gaussian (dotted lines) is that of the angular resolution in the direction of the major axis,  $FWHM = 67''7$ . Also displayed are the sum of the three gaussians (dotted line) and the residual after subtracting this sum from the data (bold dashed line). Measured values are listed in Table 1.

major axis and their relative intensities, normalising that of the strongest peak to unity, are tabulated in Table 1. The zero point of the radial axis is the position of the radio continuum maximum, which we assume to be associated with the galaxy centre. A justification for using a three-gaussian approximation lies in the structure of the 1.49 GHz radio continuum emission distribution, where three emission maxima are visible (Condon et al. 1996). A cut through the 1.49 GHz map (with an angular resolution of  $15''$ ) is displayed in Fig. 3. The corresponding offset and intensity values were measured by us and are also listed in Table 1. A direct comparison of the radial offsets and flux densities shows that, although both emission distributions can be approximated by the same model, neither the positions nor the relative intensities of the peaks coincide. The central HI component is located, within the measuring accuracy, at the position of the central radio



**Fig. 3.** Cut through the 1.49 GHz radio continuum distribution of NGC 3175 along its major axis. The angular resolution is  $15''$  (Condon et al. 1996). Both the orientation and the range of this cut are identical to that presented above in Fig. 2. The same three-gaussian approximation is displayed as above. Measured values are listed in Table 1.

continuum peak (and thus the centre of the galaxy). The two outer HI components are located further out along the major axis than the extranuclear radio continuum peaks. Star formation thus takes place within the HI gas layer in the central disk, as might be expected.

The secondary HI emission feature near the southwestern edge of the galaxy disk might be a small companion or a weak remnant of a tidal spur or arm. Its recession velocity of about  $1050 \text{ km s}^{-1}$  does not match up with the velocities on that side of the galaxy disk closest to it (see below).

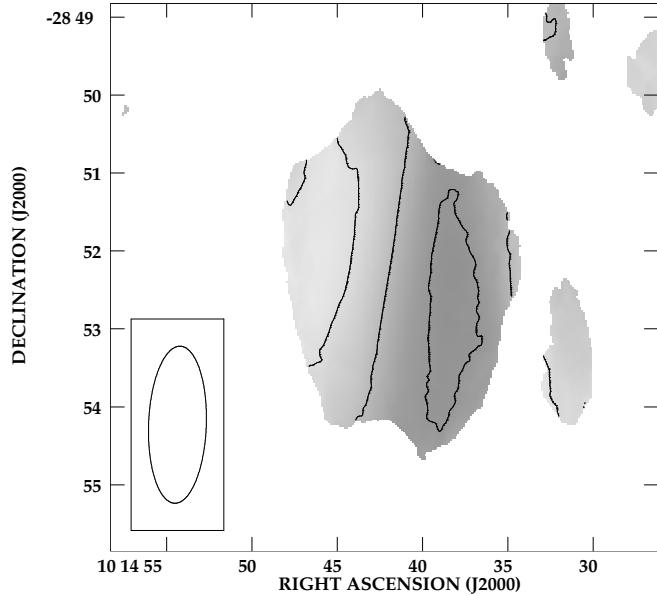
### 3.2. HI kinematics

The velocity field (Fig. 4) shows that the lowest velocities are observed in the northeastern part of NGC 3175

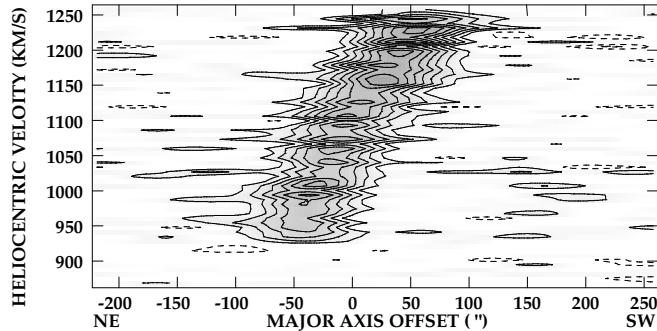
and the highest accordingly in the southwestern half.<sup>3</sup> The dust lane is located on the south-east side of NGC 3175, tracing its “near side”. This determines the sense of the galaxy’s rotation uniquely. The velocity of the secondary emission blob to the southwest is clearly similar to that of the opposite side of the disk.

A position-velocity (pv) diagram along the major axis of NGC 3175 (along  $PA = 231^\circ$ ) is displayed in Fig. 5. One can discern solid body rotation out to a radius of about

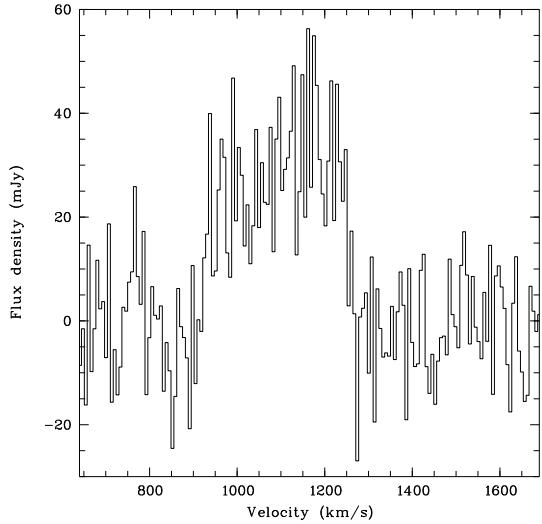
<sup>3</sup> Based on this knowledge and the convention to define the  $PA$  as the angle from North to the receding side of a galaxy, the formally correct value is  $PA = 231^\circ$ .



**Fig. 4.** The HI velocity field of NGC 3175. The grey scale ranges from minimum ( $920 \text{ km s}^{-1}$ ; light grey) to maximum ( $1270 \text{ km s}^{-1}$ ; dark grey). The contours shown are  $1025 \text{ km s}^{-1}$ ,  $1100 \text{ km s}^{-1}$  (approximately the systemic velocity) and  $1175 \text{ km s}^{-1}$ .



**Fig. 5.** Position-velocity cut through the HI line emission distribution of NGC 3175 along its major axis. The angular resolution in the direction of the major axis is  $67''$ , the velocity resolution is  $6.6 \text{ km s}^{-1}$ .



**Fig. 6.** Integral HI line spectrum of NGC 3175 measured with the ATCA. The velocity resolution of the displayed data is  $6.6 \text{ km s}^{-1}$ . The velocities on the x-axis are heliocentric.

$\pm 45''$  from the centre of the galaxy. A comparison with Fig. 3 by Mathewson et al. (1992) reveals that the velocity gradient is not so low because of beam smearing effects, but the same gradient is observed in  $\text{H}\alpha$ , with much higher angular resolution. However, it is unusual for spirals of types earlier than Scd not to have any HI gas beyond the turnover radius in the rotation curve.

The secondary emission blob is not visible here because of its low signal-to-noise ratio. It arises from several marginally positive signals in the channels in the range  $1000$ – $1050 \text{ km s}^{-1}$  (at a radial offset of about  $120''$ – $200''$ ).

### 3.3. Total HI line flux and gas mass

The total HI line spectrum of NGC 3175 is displayed in Fig. 6. The integral HI line spans a velocity range of  $350 \text{ km s}^{-1}$ , from  $920$  to  $1270 \text{ km s}^{-1}$  (cf. also Fig. 5), with an approximate width at 20% of the peak of  $W_{20} = 330 \text{ km s}^{-1}$ . From the integral spectrum we derive a heliocentric systemic velocity of  $v_{\text{hel}} = 1095 \pm 10 \text{ km s}^{-1}$ , which is compatible with earlier measurements. The integral line flux from NGC 3175 is  $11.0 \text{ Jy km s}^{-1}$ , with an estimated uncertainty of about 20%, which is roughly compatible with the non-detection reported earlier, with an upper limit of  $8.3 \text{ Jy km s}^{-1}$  (Mathewson et al. 1992). Our HI flux measurement is only slightly lower than the values obtained by Mathewson & Ford (1996) of  $14.64 \text{ Jy km s}^{-1}$  and Theureau et al. (1998) of  $12.9 \pm 1.2 \text{ Jy km s}^{-1}$ . One can estimate the amount of flux that might possibly have been missed by our interferometer observations by taking the flux values from our ATCA data and the one from the Parkes data by Mathewson & Ford (1996) at face value. Our measurement reflects the amount of HI gas

in the disk of NGC 3175, while the value by Mathewson and Ford might be considered as the possible “full flux”, including low surface brightness or intergalactic HI. One can then argue that *if* any extended flux had been missed by the interferometer, it would not exceed the difference between both flux measurements, i.e. about one third of the flux displayed in Fig. 1.

The 1.344 GHz continuum flux density of NGC 3175 from our ATCA run of  $71.5 \pm 5$  mJy is in very good agreement with the value from the VLA data at 1.425 GHz (Condon et al. 1996) of 71.8 mJy. Thus, the relative calibration between our data and the VLA is good. Because of the weak continuum emission, one can assume that the measured total HI line flux is not measurably influenced by intrinsic self-absorption. Our continuum map is not displayed here, because it does not add anything new to what is already known from the one by Condon et al. (1996).

Using the relation by Roberts (1975) in Eq. 1 and assuming optically thin emission, we can calculate the HI gas mass in NGC 3175 from the integral HI line flux as follows:

$$M_{\text{HI}} = 2.356 \cdot 10^5 \cdot D^2 \cdot f_{\text{HI}} [M_{\odot}] \quad , \quad (1)$$

where  $D$  is the distance in units Mpc and  $f_{\text{HI}}$  is the measured integral HI line flux.  $f_{\text{HI}} = 14.64 \text{ Jy km s}^{-1}$  (from the Parkes data by Mathewson & Ford 1996) then translates into a total HI gas mass of NGC 3175 of  $7.8 \cdot 10^8 M_{\odot}$ , which is quite low for an Sa–Sc type spiral. Other late-type spirals have HI gas masses of order  $10^9 - 10^{10} M_{\odot}$ , typically (e.g. Rhee & van Albada 1996).

The HI line flux of  $f_{\text{HI}} = 11.0 \text{ Jy km s}^{-1}$  measured from our data corresponds to an HI gas mass of  $5.8 \cdot 10^8 M_{\odot}$ . This implies that there are, if any, only small amounts ( $2 \cdot 10^8 M_{\odot}$ ) of intergalactic HI gas in the vicinity of NGC 3175 that might have such a low surface brightness as to be missed by the ATCA.

Thus, our present observations prove the presence of small amounts of HI gas in the inner disk of NGC 3175, an area where other tracers of star formation (SF) processes had been detected previously. Elfhang et al. (1996) report the detection of CO emission from the central part of NGC 3175. It appears that the gas from which stars can be formed has finally been detected in emission.

One can use the CO(1–0) line flux derived by Elfhang et al. (1996) of  $f_{\text{CO}} = 19.3 \pm 1.4 \text{ K km s}^{-1}$  (on the  $T_{\text{mb}}$  main beam temperature scale) to calculate an estimate of the total molecular gas mass of NGC 3175. This estimate is a lower limit, because only one beam area ( $FWHM = 44''$ ; Elfhang et al. 1996) was observed. Assuming that the radial CO emission distribution is similar to that of the radio continuum, as observed in many galaxies (see for example García-Burillo et al. 1992), the CO emission of NGC 3175 should arise from within the central  $90''$ . At the high inclination angle of NGC 3175, the apparent thickness of the disk will probably be only a few arcseconds, thus contained within the SEST beam. Based on the fact that the CO spectrum is peaked near the systemic velocity

**Table 2.** Basic properties of NGC 3175<sup>a</sup>

Property	Symbol	Measurement
Absolute blue magnitude	$M_B$ (mag)	$-19.55 \pm 0.10$
Total blue luminosity	$L_B (L_{\odot})$	$1.03^{(+0.25)}_{(-0.20)} \cdot 10^{10}$
Total HI gas mass	$M_{\text{HI}} (M_{\odot})$	$7.8 (\pm 1.5) \cdot 10^8$
Total virial mass	$M_T (M_{\odot})$	$7.34 (\pm 0.85) \cdot 10^{10}$
HI to total mass ratio	$M_{\text{HI}}/M_T$	$1.06\% \pm 0.25\%$
HI to blue light ratio	$\frac{M_{\text{HI}}}{L_B} \left( \frac{M_{\odot}}{L_{\odot}} \right)$	$0.076 \pm 0.019$
Total mass-to-light ratio	$\frac{M_T}{L_B} \left( \frac{M_{\odot}}{L_{\odot}} \right)$	$7.13^{+1.78}_{-1.98}$
Optical colour index <sup>b</sup>	$B-V$ (mag)	$0.90 \pm 0.14$
Total FIR luminosity	$L_{\text{FIR}} (L_{\odot})$	$6.38 (\pm 0.6) \cdot 10^9$

Notes to Table 2:

a) All values calculated by us based on  $D = 15.9$  Mpc.  
b) Both  $B$  and  $V$  magnitudes are from the RC3.

of NGC 3175 it is also likely that the CO gas distribution is centrally peaked. Therefore, we estimate that the SEST has gathered *at least* 50% of the total CO(1–0) line flux from this object.

We calculate the molecular gas mass,  $M_{\text{H}_2}$ , following the relation

$$M_{\text{H}_2} = I_{\text{CO}} N(\text{H}_2)/I_{\text{CO}} D^2 \theta m(\text{H}_2) [M_{\odot}] \quad , \quad (2)$$

where  $I_{\text{CO}} = 19.3 \text{ K km s}^{-1}$  is the observed surface brightness of CO line emission,  $N(\text{H}_2)/I_{\text{CO}}$  is the CO-to-H<sub>2</sub> conversion factor (“X” factor) between H<sub>2</sub> column density and observed CO line surface brightness, for which we adopt the “standard” value of  $2 \cdot 10^{20} \text{ cm}^{-2}/\text{K km s}^{-1}$ ,  $D$  is the distance of 15.9 Mpc in units cm,  $\theta$  is the area over which emission is observed (in units sterad; here the beam  $FWHM$  of the SEST) and  $m(\text{H}_2)$  is the mass of an H<sub>2</sub> molecule of  $1.68 \cdot 10^{-57} M_{\odot}$ .

Filling in these quantities, we determine that  $M_{\text{H}_2} \geq 5.8 \cdot 10^8 M_{\odot}$ . This infers a ratio of  $M_{\text{H}_2}/M_{\text{HI}} \geq 0.74$ .

In the context of the results by Young & Knezek (1989), this makes it likely that NGC 3175 is an Sc type spiral. If up to 50% of the total CO line flux should have been missed, the corrected ratio is also still consistent with an Sb–Sbc classification. This ratio of 0.74 would be unusual for a galaxy of type earlier than Sb though.

## 4. Discussion

### 4.1. Global properties of NGC 3175

In order to interpret the HI gas properties of NGC 3175 in general terms and compare the galaxy with other spirals, we have calculated a few standard properties, as tabulated in Table 2. The far-infrared luminosity,  $L_{\text{FIR}}$ , was taken from Dahlem et al. (2001).

The total virial mass,  $M_T$ , was calculated using the formula

$$M_T(r) = 2.33 \cdot 10^5 \cdot r \cdot v^2(r) [M_{\odot}] \quad , \quad (3)$$

where  $r_{25} = 2.5'$ , the 25th magnitude isophotal radius, was used as a measure of  $r$  and half the width of the

integral HI spectrum,  $W_{20}/2 = v_{\max} = 165 \text{ km s}^{-1}$ , as  $v(r)$  (see Figs. 5 and 6), adopting an inclination of  $i \simeq 90^\circ$ .

From a comparison of the values in Table 2 with the data by RH94 (in particular their Figs. 2–5), one can conclude the following:

- The total blue luminosity,  $L_B$ , of NGC 3175 is quite normal for a spiral of type Sa–Sc.
- Its total virial mass,  $M_T$ , lies near the 25%-level for galaxies of type Sa–Sc in the sample by RH94.
- Accordingly, the total mass-to-light ratio of NGC 3175,  $M_T/L_B$ , also lies near the 25%-level in RH94's sample.
- The total HI gas mass of NGC 3175 is relatively low (near the 25%-level) if it were an Sa or Sab galaxy; for types Sb–Sc, it is well below the 25th percentile mark of the data used by RH94, indicating an HI deficiency.
- The ratio of HI gas mass to total mass of only about 1% is at about the 25%-level in RH94's data if it were an Sa or Sab galaxy. For all later types, this percentage represents a pronounced deficiency (because there is little variance in the ratios for spirals of type Sb or later). Note that if we use our own HI line flux measurement this deficiency is yet much more pronounced, with an HI-to-total mass ratio of only 0.8%.
- The same is true for the  $M_{\text{HI}}/L_B$  ratio.
- Even for an Sa galaxy, NGC 3175's  $B-V$  colour is unusually red, being far beyond the 75%-level of RH94's data. For galaxies of later types the discrepancy is yet more pronounced. NGC 3175 is in fact one of the reddest nearby spiral galaxies, with a predominantly old stellar population. The same was already found by Ryder & Dopita (1993).
- On the other hand, its FIR luminosity,  $L_{\text{FIR}}$ , is normal for galaxies of types Sa–Sc.

One should note that  $L_B$ ,  $M_T$  and  $L_{\text{FIR}}$  do not show a strong dependence on Hubble type (see RH94). On the other hand, quantities like  $M_{\text{HI}}$ ,  $M_{\text{HI}}/L_B$  and  $M_{\text{HI}}/M_T$  do show a dependence of Hubble type (albeit with considerable overlaps). According to these properties, NGC 3175 shows an HI deficiency. For type Sa–Sab, this deficiency would not be very pronounced, but if NGC 3175 should be of a later Hubble type, its HI content is clearly deficient.

#### 4.2. Star formation in the central disk

HI gas has been found by us, corroborating earlier detections; as stated above, NGC 3175 is HI-deficient. The ATCA data provide for the first time spatially resolved information. Our total HI intensity map in Fig. 1 indicates that most of the detected HI gas is located within the central part of the galaxy. Because this is difficult to quantify by looking at the map only, we have produced the radial cut through the emission distribution shown in Fig. 2. From the position of the gauss components (see also Table 1) it follows that practically all HI gas is contained within the central 7 kpc, and that the ongoing SF

is enveloped by HI gas. It is very unusual that HI is detected only in the central  $90''$  (7 kpc) of NGC 3175, while normally the stellar disks of spiral galaxies are embedded in extended HI envelopes (Bosma 1981). The radial extent of the HI distribution in NGC 3175 roughly coincides with that of the  $\text{H}\alpha$  and 1.4 GHz radio continuum emission (Ryder & Dopita 1993; Condon et al. 1996). Therefore, only the central part of the disk is apparently forming stars at the present time. This is corroborated by the fact that this is the only region in NGC 3175 with optical colours suggesting the presence of a young population of stars (Ryder & Dopita 1994). All over this central area the HI gas follows a solid body rotation pattern (Fig. 5).

There is no reliable estimate on the total molecular gas content of NGC 3175 in the literature and it is doubtful that Elfag et al. (1996) measured the total CO line flux of NGC 3175 within one  $44''$  beam of the Swedish-ESO Submillimetre Telescope. Still, the CO spectrum by Elfag et al. (1996) can serve to give a first impression of the molecular gas properties of the nuclear area in NGC 3175. Its peak antenna temperature of ca. 0.15 K is quite typical for galaxies at a distance of 15.9 Mpc (see also for comparison Young et al. 1995). This and the numbers derived above suggest that HI gas, which is normally more extended than CO, might be more deficient than molecular gas.

Inside the inner disk of NGC 3175, within a radius of 3.5 kpc, the density of cold atomic and molecular gas appears to be high enough for the onset of SF. In fact, the FIR properties of the inner disk in NGC 3175, especially its  $f_{60}/f_{100}$  flux ratio of 0.46 and the implied warm dust temperatures, are reminiscent of starburst galaxies with disk-halo interactions (e.g. Heckman et al. 1990; Dahlem 1997). This is consistent with the observed radio continuum emission distribution which indicates the presence of an outflow from the H II regions in the central disk into the halo (Condon et al. 1996, Dahlem et al. 2001). Since all SF activity is visibly occurring in the central 7 kpc of NGC 3175, it can be assumed that the FIR emission comes from that same region.

#### 4.3. The quiescent outer disk of NGC 3175

Virtually no HI gas was detected beyond a radius of 3.5 kpc (see Fig. 2) with the sensitivity of the current data. At the same time, the outer disk of NGC 3175 exhibits no measurable signs of ongoing SF. There is neither  $\text{H}\alpha$  nor radio continuum emission and there is also no sign of a young, blue population of stars. The outer disk of NGC 3175 does show signs of spiral arms; thus it can be assumed to rotate differentially, but there is not enough gas to trace its rotation pattern.

Such a situation, and also the observed activity in the inner disk, might be created by an interaction (possibly a distant passage of a companion) in the past, which could have affected the outer, volatile neutral atomic gas

component, but not the more centrally concentrated and therefore more stably bound molecular gas (e.g. Kenney & Young 1989). RH94 and Giovanelli & Haynes (1988) note that interacting galaxies in groups can lose up to 50% of their gas, galaxies in clusters even up to 90%.

All this would also be consistent with the exceptionally red colour of NGC 3175's disk beyond a radius of 3.5 kpc, because a gravitational interaction could remove part of the gas from the outer disk, while a fraction of the remaining gas would move into the central region (e.g. Combes 1987). The outer, quiescent disk dominates the mean  $B-V$  colour index of NGC 3175, because it covers about 90% of the surface area.

#### 4.4. The “missing” HI gas

Our HI observations cannot explain where the HI gas is that must at one point in time have been present in the outer disk of NGC 3175. Except the one weak emission blob to the south-west of NGC 3175, which is negligible in terms of its gas mass ( $0.8 \text{ Jy km s}^{-1} \doteq 4.2 \cdot 10^6 M_{\odot}$ ), our HI data show no sign of emission from either tidal features (like tails, plumes, tidal arms or any other sort of intergalactic or galactic emission from a potential optically faint partner) within a radius of  $15'$  (70 kpc). These results are consistent with those of García (1993), according to whom NGC 3175 is a member of a group of 5 galaxies, none of which is close enough (in spatial projection and at the same time in velocity space) to be directly interacting with it at the current time (Table 2 by García 1993).

A look at the DSS does not help in proposing a likely scenario for the removal of gas from NGC 3175 either. There is no visible interaction partner near NGC 3175 (within a projected distance of  $50'$ , i.e. 230 kpc) massive enough to have stripped it of a significant fraction of its HI gas. ESO 436-G004, about  $5'$  south of NGC 3175, is at a different redshift and thus distance (and therefore not detected in our observations). Two small objects  $1'$  west of ESO 436-G004 that are visible on the second generation DSS (DSS-2) plates, if at approximately the distance as NGC 3175, must be dwarf galaxies.

Our ATCA data are most sensitive to structures with a spatial extent similar to the beam size and the sensitivity after only one aperture synthesis is still limited. Thus, a non-detection of intergalactic HI gas in this data set does not necessarily impose strong constraints on its potential properties. However, the presence of substantial amounts of HI gas in an area of about  $10'$  around NGC 3175 is ruled out by the Parkes data (see above). Also the new Parkes multi-beam survey database, which was searched by us, does not exhibit any signs of HI emission in the relevant redshift interval closer to NGC 3175 than  $1.3$  (or 360 kpc), where NGC 3137, one of the group members, is detected. Therefore, the riddle about the fate of NGC 3175's HI gas remains unsolved for the time being. It is not clear where it might have gone or whether NGC 3175 ever had more

HI gas than is detectable at the present time. Certainly there must have been HI gas in the outer disk before from which the observed old stellar population formed.

The fact that NGC 3175 is not a member of a cluster of galaxies, but at the same time HI-deficient, makes this deficiency with simultaneously ongoing SF in its inner part so intriguing. However, a more solid interpretation of this issue must await high-resolution HI and CO imaging observations.

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